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Reducing Children's Blood Lead Levels at the Bunker Hill Superfund Site in Northern Idaho, USA through Health Intervention and Soil/Dust Source Control Measures

Presented at the:

1994 International Lead Abatement and Remediation Conference

Newcastle, New South Wales

Australia

June 3, 1994

Prepared by:

TerraGraphics Environmental Engineering
121 South Jackson St.
Moscow, ID 83843

Ian H. von Lindern, P.E., Ph.D.

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by Ian H. von Lindern and Jerry Cobb

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Abstract/Summary

Significant reductions in lead absorption among children living on the Bunker Hill Site have been achieved in the course of the Superfund effort. Overall, blood lead levels have decreased by about 70% in this ten-year effort implemented in 1984. From 1983 to 1993, preschool blood lead levels within one mile of the Smelter decreased from a mean of 21 μg/dl to 6.7 μg/dl. From one to two and one-half miles, levels decreased from 17 μg/dl to 6.3 μg/dl. From two and one-half to five miles, the reduction has been from 12 μg/dl to 3.5 μg/dl.

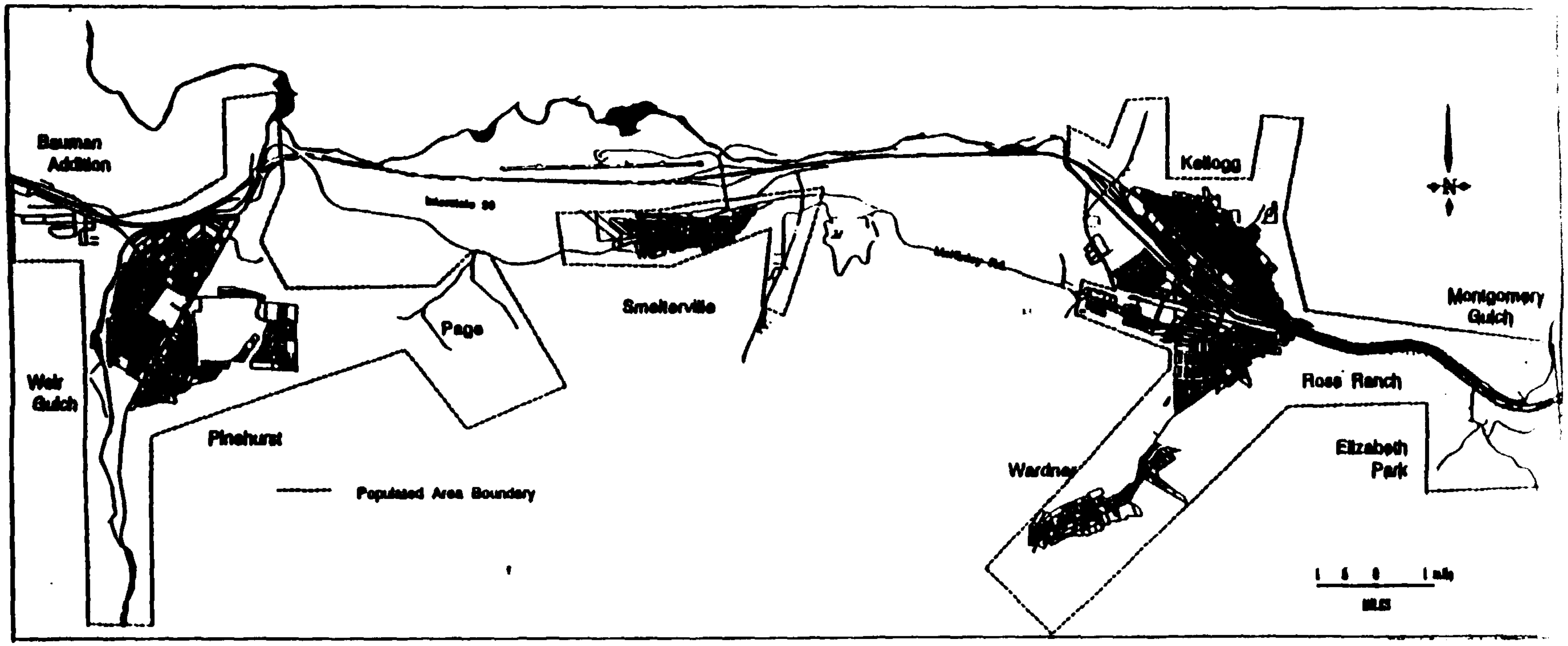
These blood lead reductions have been achieved through the aggregate effect of several activities, including:

- The Lead Health Intervention Program that promotes awareness among area parents and children (1985-1993) through education, biological monitoring and follow-up counseling.
- A community-wide cleanup program that removed contaminated soils from public parks, playgrounds, and roadsides (1986).
- Dust control efforts to mitigate fugitive dust sources of lead particulate (1987 and 1990-93).
- The Yard Soil Removal Program that replaced contaminated soils in home yards of young children throughout the site (1989-93).
- National initiatives to reduce lead in the diet.

Background

This 21 square mile Superfund site surrounds the former Bunker Hill Company lead/zinc mining and smelting complex near Kellogg, Idaho (Figure 1). The site encompasses the 365 acre abandoned industrial complex and five cities and residential areas of approximately 5,000 people.

Figure 1
Bunker Hill Superfund Site Map



TerraGraphics

The site is located in the steep mountain valley of the South Fork of the Coeur d'Alene River. Most of the residential neighborhoods and the abandoned complex are located on the valley floor, side gulches, or adjacent plateau areas. The area is heavily contaminated with heavy metals as a result of a century of mining, smelting, and refining operations.

The principal sources of metal contamination were emissions from the smelter operations and mine and mill tailings either discharged to the river or its tributaries, or confined in large waste piles on site. Approximately 1,100 acres of the valley floor is flood plain severely contaminated by tailings from mining operations early in this century. Decades of sulfur oxides emissions from smelter operations have resulted in denuding of the adjacent hillsides and severe erosion. There has been significant redistribution of smelter and mine wastes throughout the area due to reworking of soils by the river, wind, and anthropogenic activities.

The result of these various activities is ubiquitous heavy metal contamination of soils and dusts throughout the site. Typical lead concentrations of wastes and soils within the abandoned industrial complex range to ten percent or more. Tailings in the river floodplain average 2% lead. Soils in home yards in the smelter communities averaged 2,500 mg/kg to 5,000 mg/kg in the early 1980s. House dust lead concentrations averaged 2,000 mg/kg to 4,000 mg/kg at that time.

The community was the scene of a severe lead poisoning epidemic in the 1970s, resulting from improper operation of the lead smelter. Nearly every child in the community was lead poisoned at that time due to extreme air pollution and atmospheric fallout. Mean blood lead levels of children living within one-mile of the complex were near 70 $\mu g/dl$. Air lead levels averaged near 20 $\mu g/m^3$, soil lead concentrations near 7,500 mg/kg, and house dust lead levels approximately 12,000 mg/kg.

The smelter closed in 1981, and activities under the U.S. Superfund Program commenced in 1983 with a special Lead Health Study. Despite smelter closure, mean blood lead levels among pre-school children in the one-mile area exceeded 20 $\mu g/dl$ due to exposures to residual soil and dust contamination.

In 1985, Superfund remedial investigations were initiated along with the Lead Health Intervention program designed to minimize lead absorption through health education, parental awareness, and biological monitoring efforts. In the interim, several source control activities have been undertaken, including cleanup of area parks, playgrounds, and roadsides in 1986; smelter stabilization efforts from 1989-93; hillsides revegetation and fugitive dust control efforts from 1990-93; and the Yard Soil Removal Program that replaced contaminated soils in home yards of young children from 1989-93.

During the entire effort, an extensive data base has been maintained that relates children's blood lead levels, media contaminant concentrations, environmental exposures, and remedial activities on an individual basis. Blood lead levels and environmental data have been collected on more than 2,500 children in the last 6 years. The overall data base extends to 1974 and includes more than 5,000 observations in total. This data base contains individual medical, health, and property information, and is maintained as confidential health records. Only summary and non-confidential data are released publicly.

Extensive analyses of these data have been conducted to support project activities including:

- Identification and characterization of exposure pathways,
- Identification of important factors in childhood lead poisoning,
- Targeting of intervention activities,
- Assessing the effectiveness of intervention and removal efforts,
- Developing cleanup criteria and Remedial Action Objectives (RAOs) for remediation, and
- Developing cleanup strategies to meet RAOs.

The site RAOs with respect to lead absorption are to reduce the incidence of lead poisoning in the community to:

i) Less than 5% of children with blood lead levels of 10 μg/dl or greater, and

ii) No individual child exceeding 15 μg/dl (nominally, <1% of population).

These objectives are to be achieved by a strategy that includes:

i) Replacing all yards with soil lead concentrations greater than 1,000 mg/kg;

ii) Achieving a geometric mean yard soil concentration of less than 350 mg/kg for each community on the site; and

iii) Extensive fugitive dust control efforts, and stabilization and cover of contaminated soils throughout the site.

The success of this strategy ultimately depends on interior house dust lead levels decreasing to concentrations comparable to post-remedial soils (i.e., < 500 mg/kg). In the event that house dust lead levels remain elevated, homes with concentrations greater than 1,000 mg/kg will receive interior remediation.

Historic Blood Lead and Environmental Exposure Levels

Blood lead, environmental exposure, and media concentration data are presented both by town and Area. Area 1 encompasses a one mile radius of the smelter and includes the City of Smelterville. Area 2 is from 1 to 2½ miles from the complex and includes Kellogg, Wardner, and Page. Area 3 is from 2½ miles to the site boundary and includes Pinehurst. Figure 1 shows these cities.

Figures 2 through 5 summarize overall trends in blood, air, yard soil, and house dust lead levels since the epidemic years of 1974-75. These figures provide perspective as to the levels of lead contamination and childhood poisoning in these communities over the last three decades. Notations on these figures indicate the more significant events associated with marked increases or decreases in blood lead levels.

Blood Lead Levels: Lead poisoning was epidemic in these communities in the 1970s. During 1973-74, the smelter was operated without full air pollution control facilities following a fire in the

Figure 2

Blood Lead Level by Year 1974-1993

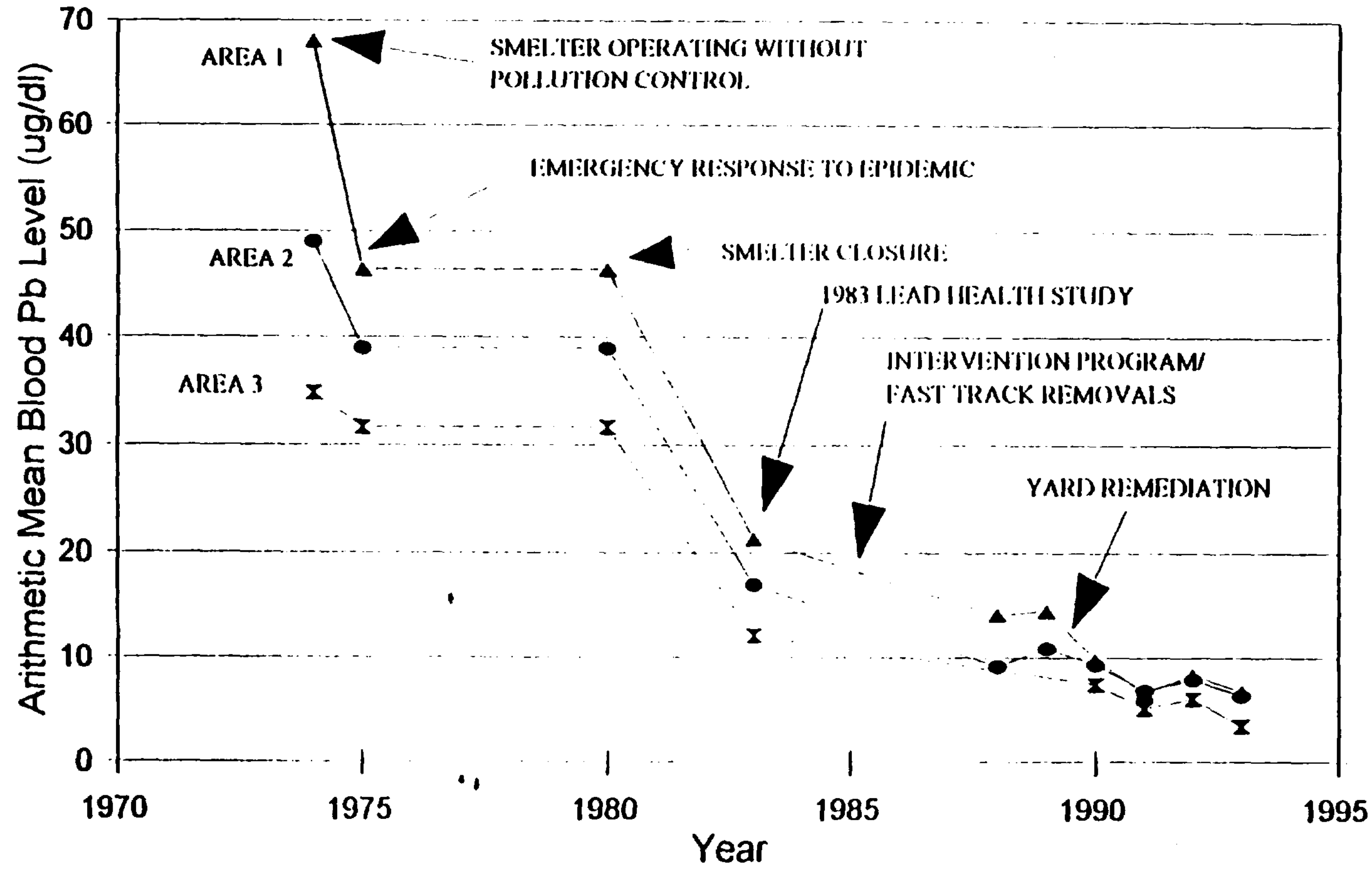


Figure 3

Air Lead Exposure by Year 1971-1993

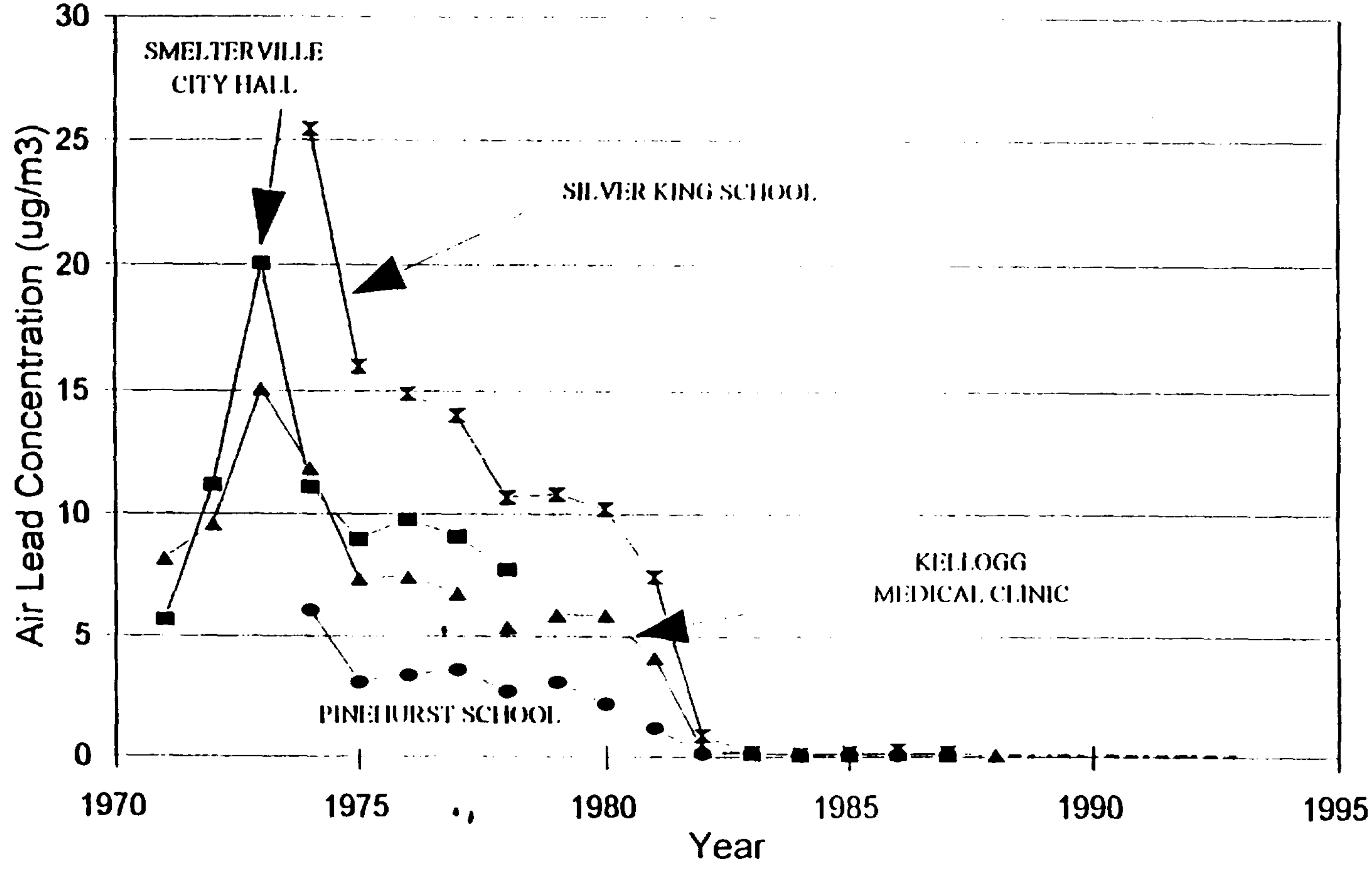
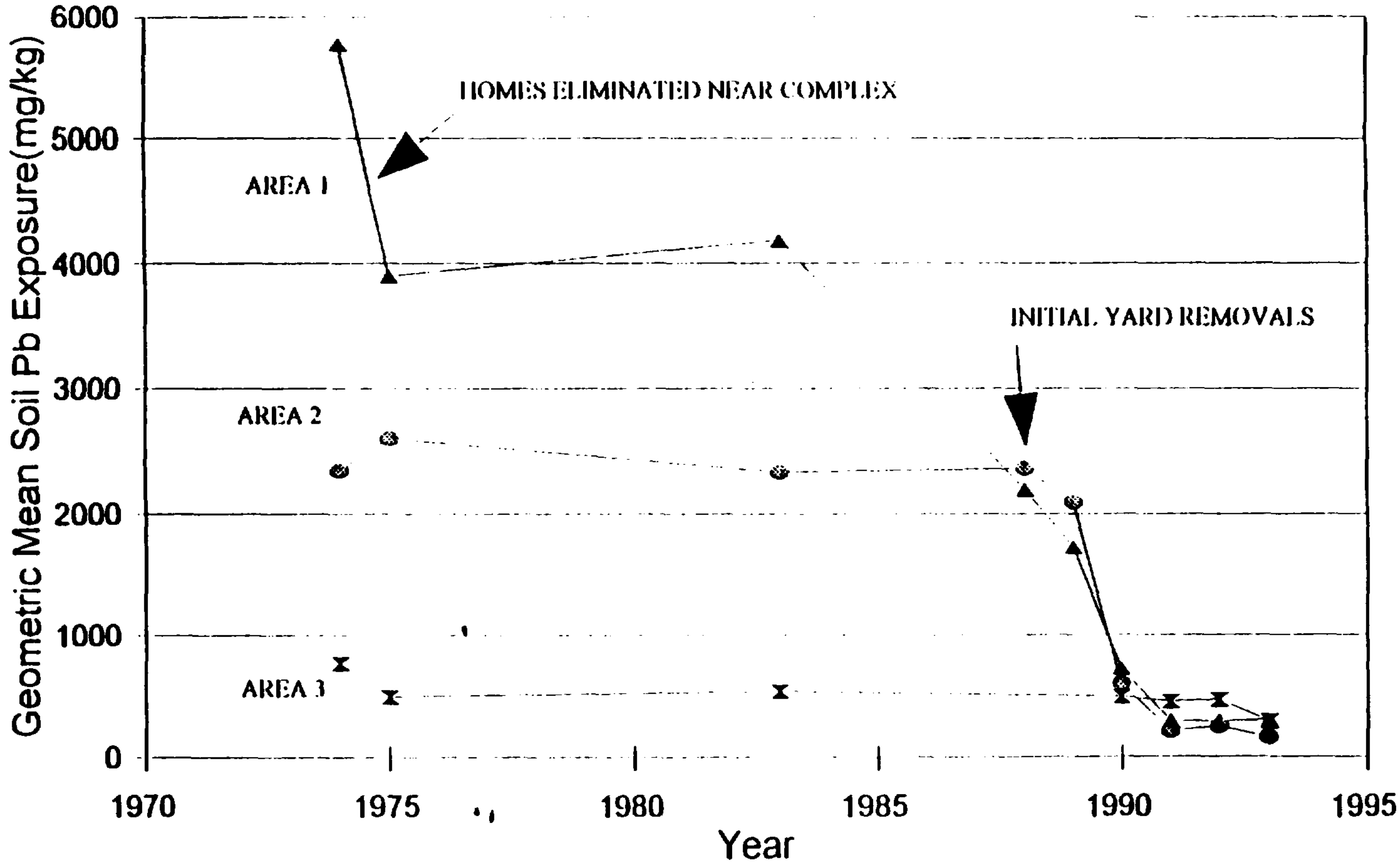


Figure 4

Yard Soil Lead Exposure by Year 1974-1993



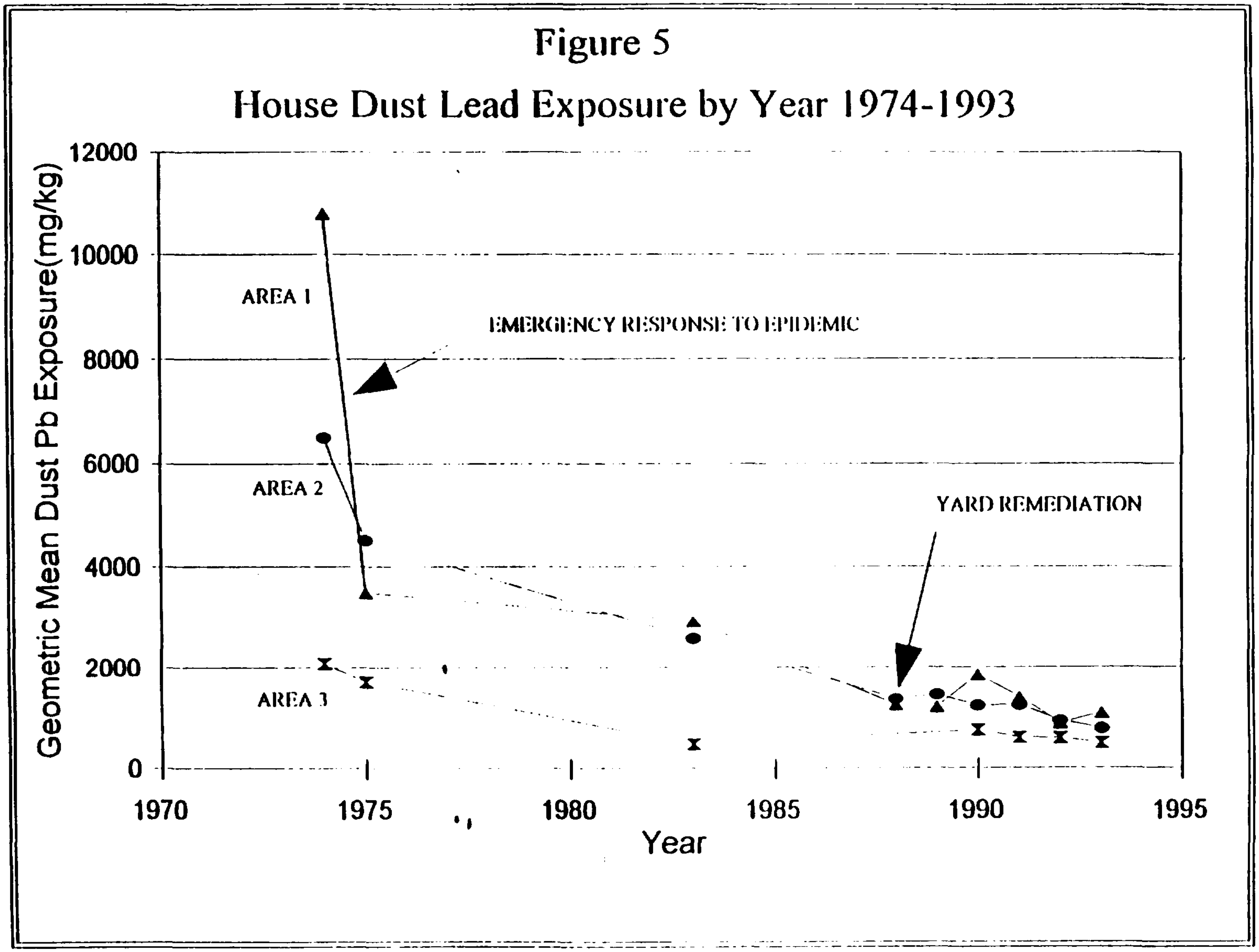


Figure 5
House Dust Lead Exposure by Year 1974-1993
Geometric Mean Dust Pb Exposure(mg/kg)
12000
10000
8000
6000
4000
2000
0
AREA 1
AREA 2
AREA 3
EMERGENCY RESPONSE TO EPIDEMIC
YARD REMEDIATION
1970
1975
1980
1985
1990
1995
Year

main baghouse. Excessive smelter emissions and the resulting air lead levels and deposition of fine high-lead content particulate in area soils and dusts were the principal contaminant migration routes to young children. Average blood lead levels among pre-school children within one-mile of the complex (Area 1-Smelterville) were near 70 $\mu g/dl$. Dozens of children were diagnosed with clinical lead poisoning and several were hospitalized and treated with chelation (EDTA) therapy. Emergency response actions taken in 1974-75 reduced absorption by about 20% by 1976. However, mean blood lead levels among preschool children remained near 40 $\mu g/dl$ until smelter closure in 1981.

Children's blood lead levels were monitored in the 1983 Lead Health Survey. Mean blood lead levels in Area 1 preschoolers were about 21 $\mu g/dl$ and were, in large part, impetus for implementing both the Intervention Program and RI/FS activities at the site. Blood lead levels in Areas 2 and 3 can be also seen in Figure 2 and Table 1.

Blood lead levels since 1988 are shown in Figure 6. These data demonstrate a downward trend since yard soils removals began in 1989. Increases in mean concentration of approximately 1 to 1.5 $\mu g/dl$ were noted from 1988 to 1989 and again from 1991 to 1992. Using the arithmetic mean as an index of total absorption, blood lead levels have decreased by 40-55% (5-8 $\mu g/dl$) since 1989, from highs of 14.6 $\mu g/dl$ and 10.9 $\mu g/dl$ for Areas 1 and 2, respectively, to levels of 6.7 $\mu g/dl$, 6.4 $\mu g/dl$, and 3.5 $\mu g/dl$ for Areas 1, 2, and 3, respectively, in 1993.

Environmental Media Contaminant Concentrations: Three primary environmental exposure media contribute to excess lead absorption at this site. Those media are air, soils, and house dusts. As can be seen in Figure 3, air lead levels and the fine particulate source decreased markedly in 1981 as smelter emissions ceased. House dust lead levels showed a similar, but not so abrupt, change by 1983 (Figure 5). Soil lead levels, conversely, showed little change with smelter closure (Figure 4). The decline in yard soil lead levels seen from 1974 to 1975 was due to the elimination by purchase and demolition of highly contaminated homes from the local housing base. Marked decreases in yard soil concentrations were not noted until the residential soil removal program commenced in 1989.

Because of the selective nature of the residential soil cleanup, it is important to distinguish between *yard soil lead exposures* and *community mean soil lead concentrations*. Exposures are calculated only from homes where children reside. Media lead concentrations refer to all homes in the community where data are available. Figures 8a through 8c show community wide and child-based geometric mean yard soil lead concentrations for the same period. These two concentrations are used to demonstrate the effect of the yard removal program. Because yards are selectively remediated at the homes of young children, mean soil concentrations determined on the basis of children's homes (i.e., soil lead exposures) are decreasing more rapidly than in the overall community. The broken line in Figures 8a through 8b shows the geometric mean yard soil lead concentration for all homes sampled in each area. The solid line is the geometric mean soil lead exposure for homes occupied by children 9 years of age or less.

Since 1988, total lead in yard soils (community mean) has been reduced by about 60% in

Figure 6

Blood Lead Level by Year 1988-1993

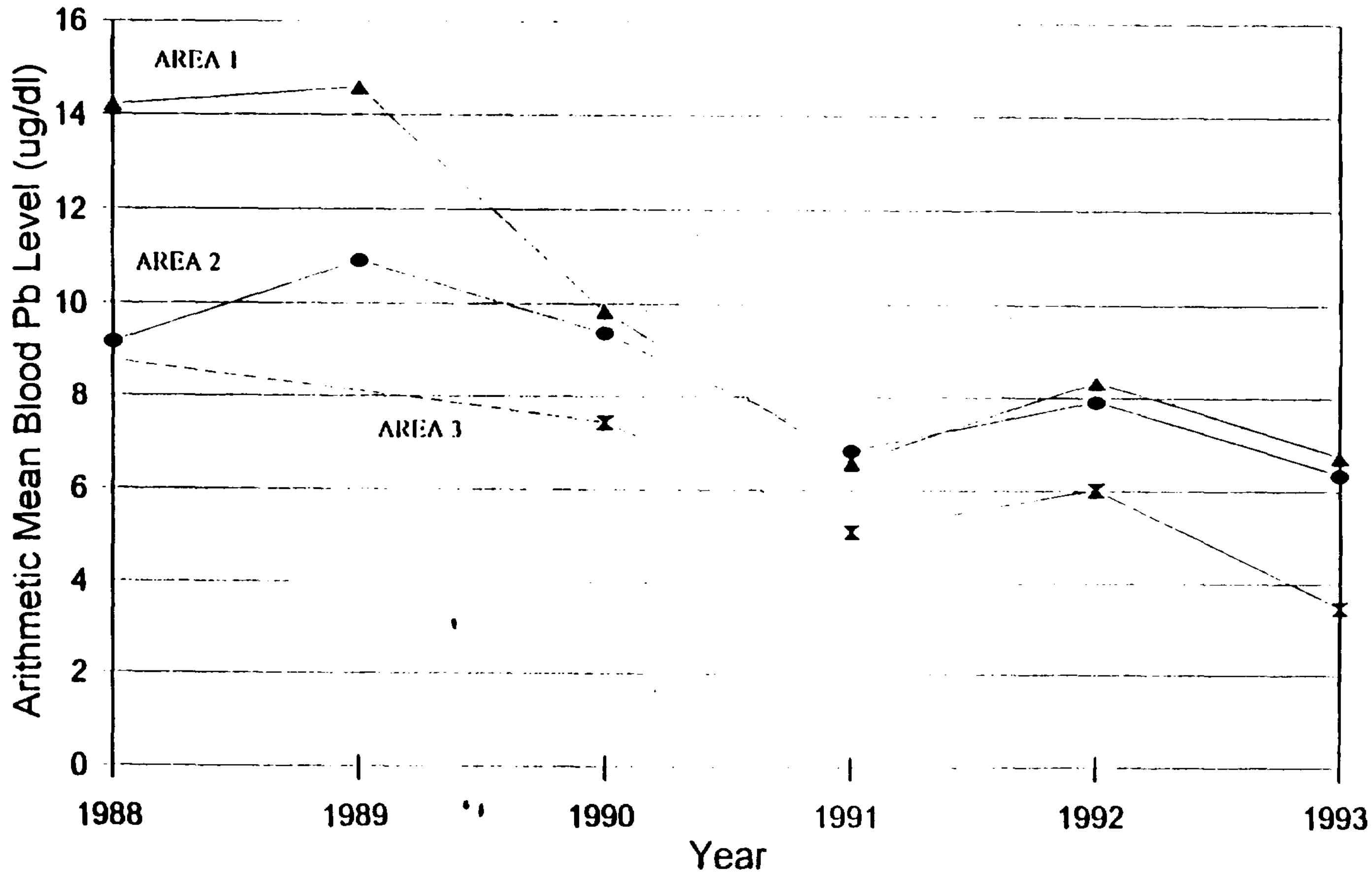


Figure 7

House Dust Lead Exposure by Year 1988-1993

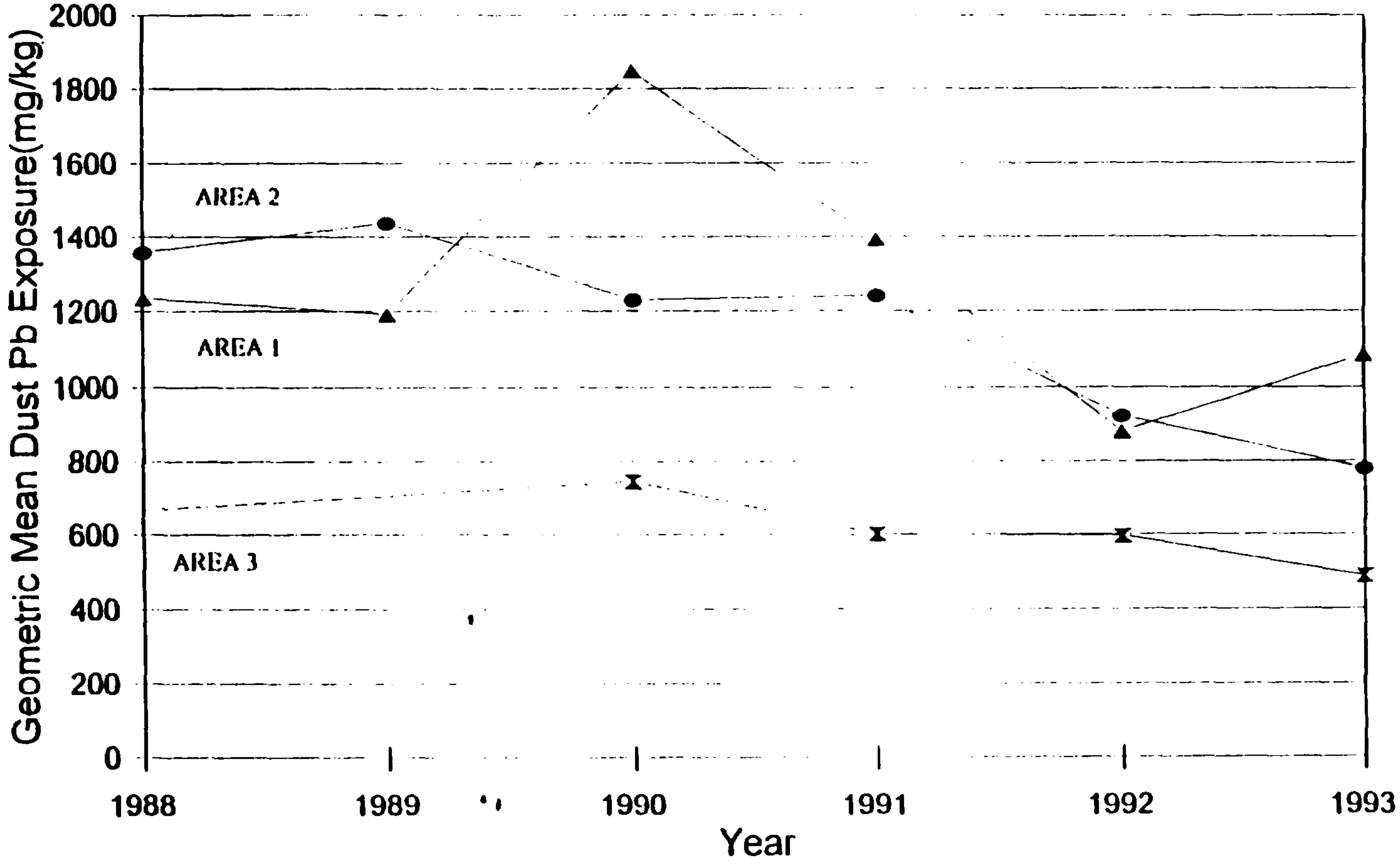


Figure 8a

Yard Soil Lead Exposure by Year 1988-1993, Area 1

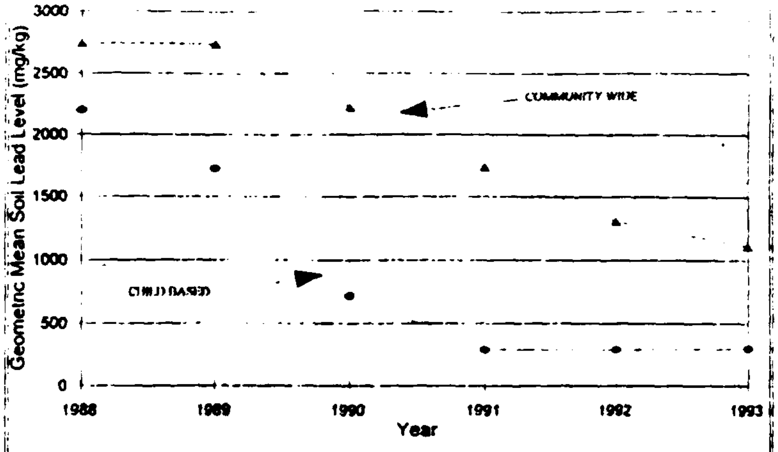


Figure 8b

Yard Soil Lead Exposure by Year 1988-1993, Area 2

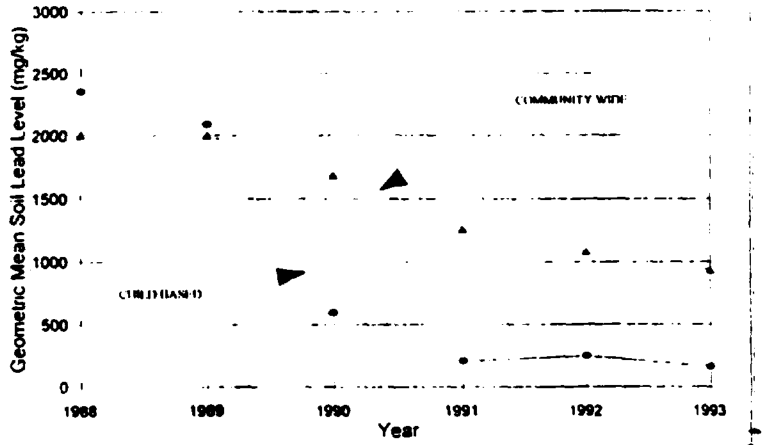
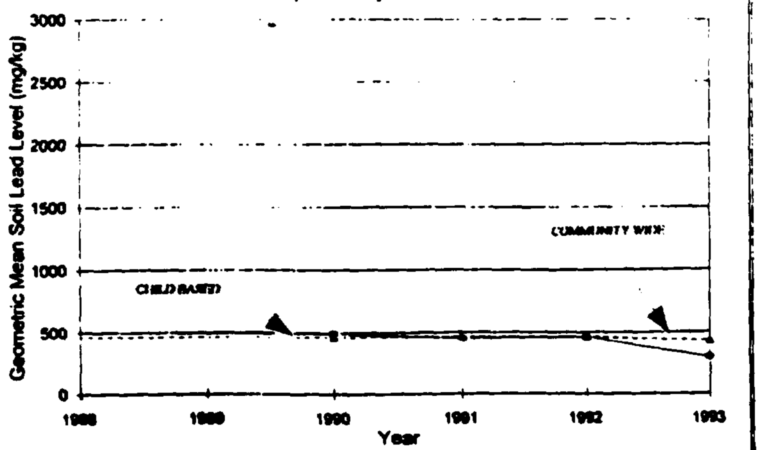


Figure 8c

Yard Soil Lead Exposure by Year 1988-1993, Area 3



Smelterville and Kellogg, 50% in Page and Wardner, and 10% in Pinehurst. Yard soil exposures to individual children have been reduced more than 80% to 95% in Smelterville and Kellogg, Wardner, and Page, and 40% in Pinehurst.

House dust lead levels decreased remarkably from 1974 to 1975 in response to air pollution control initiatives at the smelter. By 1983, house dust lead levels in Areas 1 and 2 averaged near 3,000 mg/kg and were most dependent on soil sources. Following initial soil and fugitive dust control efforts from 1985-87, house dust lead content had decreased by about 40% to 1,500 mg/kg to 1,800 mg/kg in Areas 1 and 2. Notable reductions to about 1,000 mg/kg average levels have been achieved during the last few years of yard soil remediation.

House dust concentrations have also decreased by about 35% since 1988 from geometric mean highs of 1,400 mg/kg to 1,800 mg/kg in Areas 1 and 2, to highs of 800 mg/kg to 1,100 mg/kg in 1992-93. Geometric mean house dust exposures by community since 1988 are shown in Figure 7.

Exposure and Risk Reduction Efforts

Pre-Superfund Activities: Public health response actions can be grouped in two broad categories: Health Intervention and Source Control. Lead Health intervention activities refer to efforts designed to intervene in lead absorption pathways through biological monitoring, follow-up, parental awareness and counseling, and behavior modification. Source Control refers to remedial activities that remove or isolate lead sources in the child's environment.

Both types of activities have been on-going at the site since the lead poisoning epidemic of 1974. Early interventions in the 1970s included relocation of families with susceptible children, home yard and community dust control, revegetation and greening efforts, biological (blood lead) monitoring, nursing follow-up, and parental awareness and public/school education programs. Early source control activities included smelter emissions reductions and fugitive dust control efforts.

During the 1970s, this program was largely successful in preventing and mitigating clinical lead poisoning (> 60 μg/dl) among area children. However, mean childhood blood lead levels were near 40 μg/dl throughout the 1970s and several hundred children were severely poisoned according to current criteria. The program ceased in 1981 following smelter closure and discontinued funding from the owners.

In 1983, a comprehensive survey of lead poisoning and exposures in the community showed continued excess absorption among area children, including those born since the smelter closure. This study also provided a reasonably complete picture of the sources, pathways, and risk co-factors important to lead poisoning in the area. Residual contamination in community soils and dusts was identified as the primary source of lead to children. Incidental ingestion of these soils and dusts via ordinary hand-to-mouth and play activities was the primary exposure route.

Several co-factors were found to influence the soil/dust pathway and result in higher blood lead levels. Significant co-factors included parental income and socio-economic status, parental education level, home hygiene practices, smokers in the home, nutritional status of the child, use of locally grown produce, play area cover (grass vs. exposed surfaces), number of hours spent outside, pica-like mouthing tendencies, and the child's age.

Based on this information, a comprehensive plan of intervention and risk reduction was established in 1985 to minimize lead absorption during the Superfund study phase. The plan was an integrated effort of in-home intervention, public awareness efforts, and targeted remediation activities.

Health Intervention Activities

Program Description: Health intervention efforts began on a voluntary fixed-site screening basis in 1984 and met with low participation. In 1985, an aggressive door-to-door solicitation was employed to secure capillary blood samples. In 1988, a payment-for-participation strategy was initiated for venous blood samples. Since that time, participation rates have been near 90%. The three basic elements of the intervention effort are:

- Biological monitoring/census,
- Environmental and nursing follow-up, and
- Education and awareness.

The entire at-risk community is surveyed each year in late July-early August. Door-to-door screening in each town is accomplished using local residents trained and hired part-time to canvas neighborhoods. These individuals contact each residence in the study area and identify those households with children up to age 9 years and any pregnant women. Basic data are collected; residents are solicited to have their children's blood lead levels measured; and an appointment at the local hospital is scheduled ($20 is paid to each eligible child that participates). The contents of the home's vacuum cleaner (if available) have also been collected since 1988. House dust data are also available for 1974, 1975, and 1983.

Follow-up lead health counseling consists of a public health nurse and a senior environmental health specialist contacting the parents of each child with an elevated blood lead level. They provide counseling and written information on how to identify sources of lead and reduce their child's exposure. A questionnaire is completed and educational materials are provided to the parents of children with a blood lead equal to or greater than intervention levels. Nutritional counseling and multiple vitamins with iron are also provided. A follow-up blood screen is offered (3-4 months), and it is recommended that the child's blood lead information be shared with the family physician and that the child participate in the following Summer Screening Programs.

The environmental survey includes a records search of environmental data collected from the residence; sampling of soil, dust, paint, water, etc., where appropriate; counseling regarding the avoidance of locally grown produce; education regarding play activities and play areas not associated with the primary residence; evaluation of sources of exposure associated with parental occupations, hobbies, and other household activities; evaluation of past or planned home remodeling activities; and recommendation for those without vacuum cleaners to use one of the high efficiency vacuums available through the Intervention Program (since 1991).

A public health nurse and a senior environmental health specialist are available for consultations regarding sources of exposure to lead and the management of exposure pathways. A variety of locally developed fact sheets, brochures, coloring books, and a film strip are available regarding lead and children and exposure to lead during pregnancy.

Lead health information has been integrated into existing programs offered by the local health district. This information has been added to the Well Child Program, Immunization Clinics, Woman Infant and Children (WIC) Clinics, and pregnancy screening and prenatal clinics offered by the Panhandle Health District. Pregnant women are offered blood lead testing and nutritional counseling each trimester and are advised to provide their blood lead and exposure history to their private physician.

Each year, a public health nurse visits area grade school classes at all the public and private schools. A puppet show is conducted for students in kindergarten through the third grade. The presentation covers the student's role in identification and management of exposure pathways that may affect them or their siblings. The program is presented in May so children can be reminded of the hazards of lead in soil and dust prior to summer vacation when they are at the greatest risk of exposure.

A physician awareness program has been developed to keep local physicians apprised of program activities and the services that are available. Reference materials and a resource manual regarding lead and other heavy metals have been provided to area physicians and the local hospital. Upon request, additional follow-up activities and sampling can be conducted for physicians with special concerns regarding a patient with an elevated blood lead level.

Intervention Program Summary: From 1985 to 1987, capillary EP screening protocol was used to trigger follow-up activities. All children with EP levels greater than 35 μg/dl were requested to provide a blood lead sample. Those with blood lead levels greater than 25 μg/dl were provided follow-up. A total of 911 children were tested, 56 showed elevated EP and 19 of those showed excess lead absorption.

In 1988, the Intervention Program returned to venous blood lead screening. Several factors prompted this decision. With regard to participation rate, the primary impetus for parents to include their children was the annual door-to-door reminder of health concerns and a cash incentive. Prior to 1988, this protocol provided only EP data and the parent had to be solicited a second time, without monetary incentive, to submit their child to a more traumatic procedure. The lack of success in obtaining second samples, and decreased participation rates in winter screenings, argued for soliciting one-time per year with maximum incentives to obtain the most information possible.

Additionally, there was growing concern with the adverse affects of lead poisoning and the appropriateness of CDC's 25 μg/dl blood lead health standard. Based on the need for a more reliable screening tool and a more accurate assessment of lead absorption in the community, solicitation of venous samples was initiated in 1988. Table 1 shows summary statistics for the program since 1988.

Table 1
Lead Health Intervention Summary Statistics 1988-1993

Year	# children identified in survey	mean blood lead level µg/dl	# ≥25 µg/dl	# ≥15 µg/dl	# ≥10 µg/dl	# targeted for follow-up	follow-ups completed #
1988	228	8.5	7	34	104	9	9
1989	275	9.9	8	71	154	8	6
1990*	362	7.9	2	36	103	2	2
1991*	365	5.5	2	13	50	13	2
1992*	415	6.5	3	30	89	30	25
1993*	445	5.6	1	10	66	66	61

* Includes Pinehurst

Intervention Effectiveness: In total, eighty-two (82) Intervention Program efforts were undertaken to reduce absorption among children with levels above follow-up criteria. Fifty-three (53) of these cases were judged positive (at least a 5 µg/dl or 15% reduction in blood lead in one year). Fourteen interventions showed no demonstrable effect, results for twelve (12) cases were unavailable and three (3) parents refused to cooperate.

Successful intervention efforts can be grouped into four basic categories of response. Significant blood lead reductions were achieved through the following combinations of response:

- Counseling and Moving - This group constitutes families that received counseling and moved to less contaminated areas of the site, usually from Areas 1 and 2, to Area 3.

- Counseling - This group received only counseling and no home yard remediation.

- Remediation - This group includes many children in the previous group that received counseling in the early years of the project and home yard remediation one to four years later.

- Counseling and Remediation - This group received counseling and remediation concurrently.

Most of the children in the first two groups were from the years prior to 1990. The third group consists of children that were intervened with in 1985-88, but received yard remediation in 1989-90. The last group is comprised of children from 1991-92.

Table 2 summarizes the effectiveness of these responses in reducing blood lead levels.

Table 2
Decreases in Blood Lead Levels Achieved through Health Intervention Activities

Intervention Activity	No. of Children	Range of Initial Blood Lead Levels $\mu g/dl$	Average Blood Lead Decrease $\mu g/dl$	Average % Decrease in Blood Lead Level
Counseling and Moving	11	13-42	11	43%
Counseling Only	16	15-59	15	45%
Post- Counseling Remediation	11	14-31	10	47%
Concurrent Counseling and Remediation	15	15-41	12	49%

Each of these interventions achieved similar reductions in blood lead levels. The most effective combination is concurrent counseling and remediation. This is especially true considering that this combination of responses has only been available in the last few years. These latter years are characterized by both lower blood lead levels and lower intervention criteria (i.e., intervening at 15 $\mu g/dl$ rather than 25 $\mu g/dl$.) As a result, these blood lead decreases are more difficult to achieve than those in earlier years when only counseling and moving were available as intervention tools.

The other notable record in the intervention program is associated with newcomers to the site. Several children whose parents were unaware of the lead hazards present were reported as lead poisoned at their first contact with the program. It is unlikely that these children were poisoned prior to moving to the site. Most moved onto highly contaminated yards insensitive to the danger. Intervention activities with these parents have been highly successful; sixty percent (60%), or average reductions of 12 $\mu g/dl$, were achieved in six months. However, it is unfortunate that these children were not detected earlier. An effort to inform newcomers to the community of these hazards as they move in has been initiated.

Source Control Activities

Removal Strategy/Public Areas Remediation: Analysis of the 1983 Lead Health Study suggested that approximately 80% of a typical child's lead intake was from incidental ingestion of soil and dust sources. Roughly 40% of this intake seemed to come from indoor house dusts, 30% from home yard soils, and 30% from neighborhood or community wide sources (PHD 1986; TerraGraphics 1987).

Based on this observation, a strategy of incremental removal of sources was developed in the summer of 1985. The initial plan was to remediate the broadest source groups first (i.e., common neighborhood soil and dust lead sources). This would be followed by addressing individual home yards as resources became available, and finally home interior sources. Meanwhile, the

Table 3
Yard Soil Remediation Progress 1989-1993

Year	City	Number of Homes	Number Above Action Level	Number Remediated This Year	Number Remediated Total	Mean Soil Lead Level (mg/kg) Prior To Remediation Arithmetic	Geometric
1988	Smelterville	271	238	0	0	3,715	2,745
	Page	65	24	0	0	1,043	776
	Kellogg	1,121	998	0	0	2,777	2,248
	Wardner	131	90	0	0	2,065	1,461
	Pinehurst	717	143	0	0	683	463
	Total	2,305	1,494	0	0	...	...
1989	Smelterville	271	221	17	17	3,715	2,745
	Page	65	19	5	5	1,043	776
	Kellogg	1,121	933	65	65	2,777	2,248
	Wardner	131	87	3	3	2,065	1,461
	Pinehurst	717	143	0	0	683	463
	Total	2,305	1,404	90	90	...	...
1990	Smelterville	271	201	20	37	3,474	2,223
	Page	65	16	3	8	920	633
	Kellogg	1,121	832	101	166	2,601	1,859
	Wardner	131	69	18	21	2,026	1,381
	Pinehurst	717	143	0	0	683	463
	Total	2,305	1,262	142	232	...	...
1991	Smelterville	271	178	23	60	3,191	1,735
	Page	65	14	2	10	846	560
	Kellogg	1,121	774	58	224	2,328	1,385
	Wardner	131	65	4	25	1,793	989
	Pinehurst	717	143	0	0	683	463
	Total	2,305	1,175	87	319	...	...
1992	Smelterville	271	165	13	73	2,866	1,305
	Page	65	11	3	13	797	516
	Kellogg	1,121	720	54	278	2,171	1,169
	Wardner	131	62	3	28	1,741	918
	Pinehurst	717	128	15	15	683	463
	Total	2,305	1,087	88	407	...	...
1993	Smelterville	271	165	7	73	2,682	1,111
	Page	65	11	2	13	723	456
	Kellogg	1,121	720	17	278	2,024	999
	Wardner	131	62	4	28	1,702	868
	Pinehurst	717	128	10	15	589	432
	Total	2,305	1,087	40	447	...	...

Intervention Program would address specific yards and home interiors presenting problems to individual children identified through screening.

This strategy was based both on exposure and institutional considerations. From an exposure point of view, the common sources (parks, playgrounds, fugitive dusts from roadsides and barren areas, etc.) affected all children to some degree. Eliminating these sources would benefit children across the entire population. Individual exposures to children at highest risk could be addressed in the Intervention Program. From an institutional perspective, logistic and site access problems were greatly simplified by initiating cleanup activities on publicly-owned properties. Local officials were solicited and provided assistance and cooperation in response activities.

Sufficient Superfund monies were available to remediate the public parcels in 1986. About two-thirds of the parks and playgrounds and one-half the rights-of-way in Kellogg, Smelterville, and Wardner were cleaned up during the summer and fall of 1986. Approximately 12,000 cubic yards of contaminated soils were removed and staged on-site. Dust control measures were instituted in 1987 and smelter complex stabilization has continued during 1990-93.

Yard Soil Remediation: The yard soil removal program has been conducted each summer since 1989. Approximately 100 yards are targeted for completion each year. Individual yards are selected for removal on risk-based criteria combining sensitive sub-population and environmental contaminant level information. Homes resident to pregnant women and children under 12 years of age are identified in an annual census conducted each spring. Yards at each of these eligible homes are sampled and a priority list is established based on children's age and soil lead level. Pregnant women and children under four years of age living on soils greater than 1,000 mg/kg lead are highest priority. Additional members of this sensitive sub-population may identify themselves during the summer and, finally, additional children are identified in the annual Lead Health Survey in August.

Table 3 summarizes progress on the yard remediation program. A total of 1,494 yards were estimated as being above the action level of 1,000 mg/kg lead on the site. Most of these homes were located in Kellogg and Smelterville where 85-90% of yards exceed action levels. Nearly 1,000 of these homes were in Kellogg with 238 identified in Smelterville. The remainder are in the outlying communities of Pinehurst, Wardner, Page, and other unincorporated residential areas.

By the end of the 1993 removal season, a total of 447 residences (or 30% of the total homes) exceeding 1,000 mg/kg had been remediated. By city, 30% of Kellogg, 34% of Smelterville, 63% of Page, 36% of Wardner, and 17% of Pinehurst's yards with lead concentrations greater than the action level had been remediated.

Geometric mean lead levels in soil have decreased by about 50% to 60% in Kellogg and Smelterville and now average near 1,000 mg/kg, down from about 2,250 mg/kg and 2,750 mg/kg at the beginning of the Yard Removal program.

Populations on Remediated Yards: The basic strategy of the Yard Soil Removal program was to remediate as many yards of homes with young children and pregnant women as possible. Table 4 and Figures 11 a-f show the success in reducing soil exposures in terms of the percentage of children living on clean yards (remediated or yards not requiring cleanup) for at least one year, versus children on contaminated yards (those above the action level at the time of each survey).

Prior to the yard remediation program (1988-89), about 83% of Area 1 (Smelterville) and 88% of Area 2 (Kellogg, Wardner, Page) children were living on yards above the 1,000 mg/kg action level. By 1990, that number had decreased to 54% and 48%, respectively. By 1991, the majority of children (70% and 78%) were on clean yards in Areas 1 and 2, respectively.

However, in 1992, despite continued remediation, only 71% in Smelterville and 74% in Kellogg/Wardner/Page were on clean yards. In 1992, there was an actual increase in the number of children living on contaminated yards. This increase was due to families moving into the area from an adjacent county that was experiencing a housing shortage and high rental rates compared to the Silver Valley. This trend was slowed somewhat in 1993 as 72% and 87% of Area 1 and 2 children, respectively, were on clean yards.

The effect of the progressive remediation and concurrent population in-migration on soil lead exposures can be seen in Figures 11 a-f. These histograms show the number of Area 2 children on yards of varying soil concentration for the years 1988-1993. In 1988, the median and mean soil lead exposures in Area 2 were 3,000 mg/kg and 2,000 mg/kg, respectively. Similar values were noted in 1989. By 1990, substantial numbers of children were shifting from high yard soil lead categories to the remedial column (nominally 100 mg/kg), with the median reaching the 1,000 mg/kg category in 1990 and 100 mg/kg in 1991, where it has remained. However, both the number of children on contaminated yards and the mean soil lead exposure increased in 1992 due to in-migration. In 1993, the mean soil lead exposure and the number of children on contaminated yards decreased to near 1991 levels as a result of 1992 yard soil removals. The total percentage of children on remediated yards has been nearly constant since 1991, suggesting that in-migration is off-setting the current Yard Soil Removal Program's effect on soil exposures.

Table 4
Number and Percentage of Children on Remediated and Non-remediated Yards 1988-1993

Year	City	Number of Children on Yards below the action level		Number of Children on Contaminated	Percent of children	
		Remediated Yards	Yards <1,000 mg/kg Pb	Yards >1,000 mg/kg Pb	On Clean Yards	On Contaminated Yards
1988	Kellogg	-	11	115	9%	91%
	Page	-	4	7	36%	64%
	Smelterville	-	5	24	17%	83%
	Wardner	-	3	5	38%	63%
	Site Wide*	-	23	151	13%	87%
1989	Kellogg	-	16	131	11%	89%
	Page	-	8	5	62%	38%
	Smelterville	-	10	20	33%	67%
	Wardner	-	3	8	27%	73%
	Site Wide*	-	37	164	18%	82%
1990	Kellogg	61	6	75	47%	53%
	Page	6	5	4	73%	27%
	Pinehurst	0	41	7	85%	15%
	Smelterville	9	3	14	46%	54%
	Wardner	2	8	4	71%	29%
	Site Wide	78	63	104	58%	42%
1991	Kellogg	117	0	39	75%	25%
	Page	10	2	0	100%	0%
	Pinehurst	0	55	6	90%	10%
	Smelterville	31	1	14	70%	30%
	Wardner	9	0	-0	100%	0%
	Site Wide	167	58	59	79%	21%
1992	Kellogg	135	5	57	71%	29%
	Page	8	1	0	100%	0%
	Pinehurst	1	55	7	89%	11%
	Smelterville	35	2	15	71%	29%
	Wardner	15	0	0	100%	0%
	Site Wide	194	63	79	76%	24%
1993	Kellogg	153	8	23	87%	13%
	Page	9	1	1	91%	9%
	Pinehurst	12	49	0	100%	0%
	Smelterville	39	0	15	77%	28%
	Wardner	11	0	3	79%	21%
	Site Wide	224	58	42	87%	13%

* Does not include Pinehurst

Figure 11a
Number of Children on Various Soil Lead Levels
Area 2, 1988 (Kellogg, Wardner, Page)

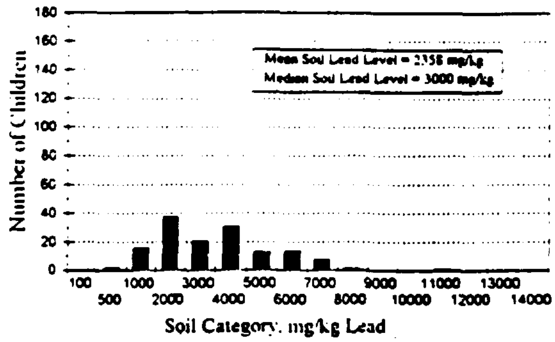


Figure 11b
Number of Children on Various Soil Lead Levels
Area 2, 1989 (Kellogg, Wardner, Page)

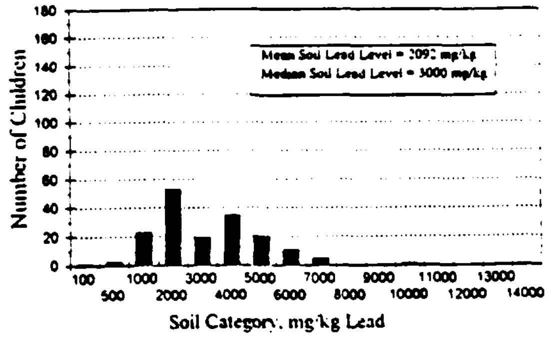


Figure 11c
Number of Children on Various Soil Lead Levels
Area 2, 1990 (Kellogg, Wardner, Page)

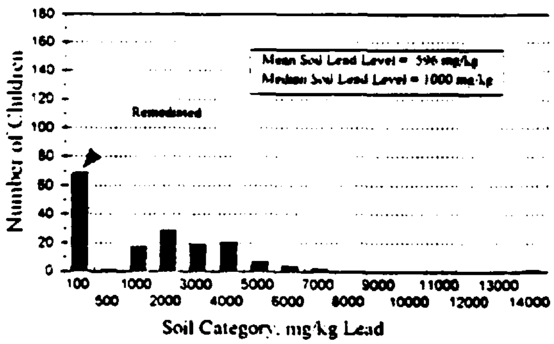


Figure 11d
Number of Children on Various Soil Lead Levels
Area 2, 1991 (Kellogg, Wardner, Page)

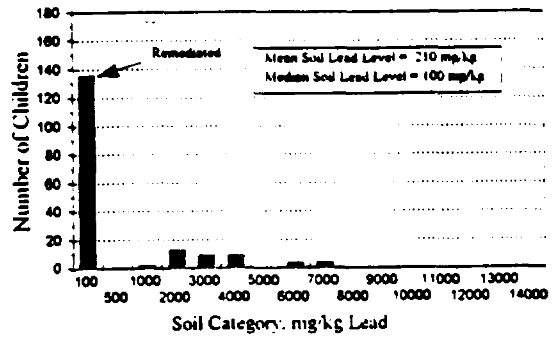


Figure 11e
Number of Children on Various Soil Lead Levels
Area 2, 1992 (Kellogg, Wardner, Page)

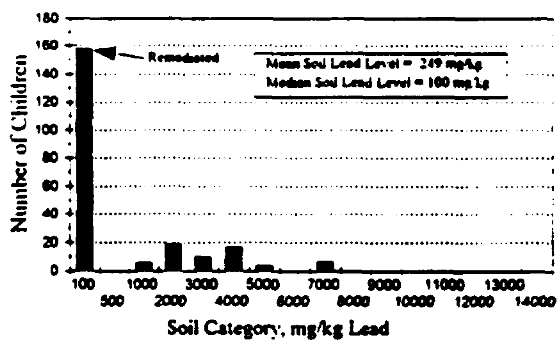


Figure 11f
Number of Children on Various Soil Lead Levels
Area 2, 1993 (Kellogg, Wardner, Page)